Natural Resources Canada | Ressources naturelles Canada

Canada

RETScreen® International

Clean Energy Project Analysis Software

Small Hydro Project Model

Clean Energy Decision Support Centre
www.retscreen.net

Training & Support
Internet Forums
Marketplace
Case Studies
e-Textbook

Partners

UNEP NASA GEF

RETScreen® Energy Model - Small Hydro Project

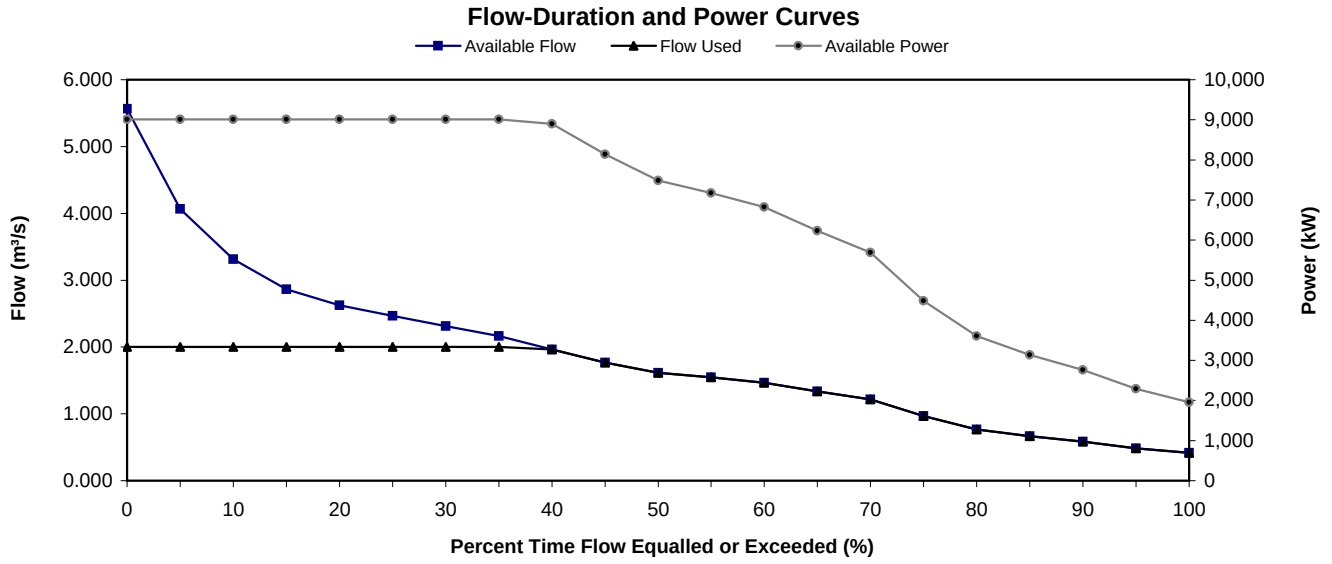
Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		High-Head	See Online Manual
Project location		Zacapa, Guatemala	
Latitude of project location	°N	15.07	-90.00 to 90.00
Longitude of project location	°E	-89.58	-180.00 to 180.00
Gross head	m	588.00	
Maximum tailwater effect	m	0.00	
Residual flow	m³/s	0.04	→ Complete Hydrology & Load sheet
Firm flow	m³/s	0.42	

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Design flow	m³/s	2.000	
Turbine type	-	Pelton	→ Complete Equipment Data sheet
Number of turbines	turbine	2	
Turbine peak efficiency	%	87.3%	
Turbine efficiency at design flow	%	85.8%	
Maximum hydraulic losses	%	3%	2% to 7%
Generator efficiency	%	96%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	1%	1% to 3%
Annual downtime losses	%	4%	2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	9,011	
	MW	9.011	
Small hydro plant firm capacity	kW	**1,957**	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	72%	40% to 95%
Renewable energy delivered	MWh	**56,906**	
	GJ	204,862	



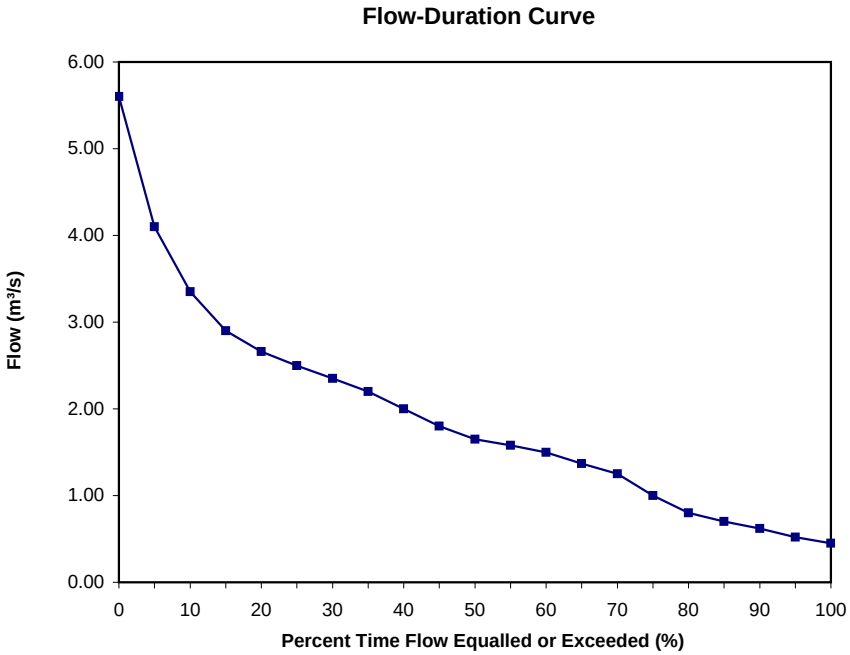
Complete Cost Analysis sheet

RETScreen® Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m³/s	0.035	
Percent time firm flow available	%	100%	90% to 100%
Firm flow	m³/s	0.42	

Flow-Duration Curve Data

Time (%)	Flow (m³/s)
0%	5.60
5%	4.10
10%	3.35
15%	2.90
20%	2.66
25%	2.50
30%	2.35
35%	2.20
40%	2.00
45%	1.80
50%	1.65
55%	1.58
60%	1.50
65%	1.37
70%	1.25
75%	1.00
80%	0.80
85%	0.70
90%	0.62
95%	0.52
100%	0.45



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	

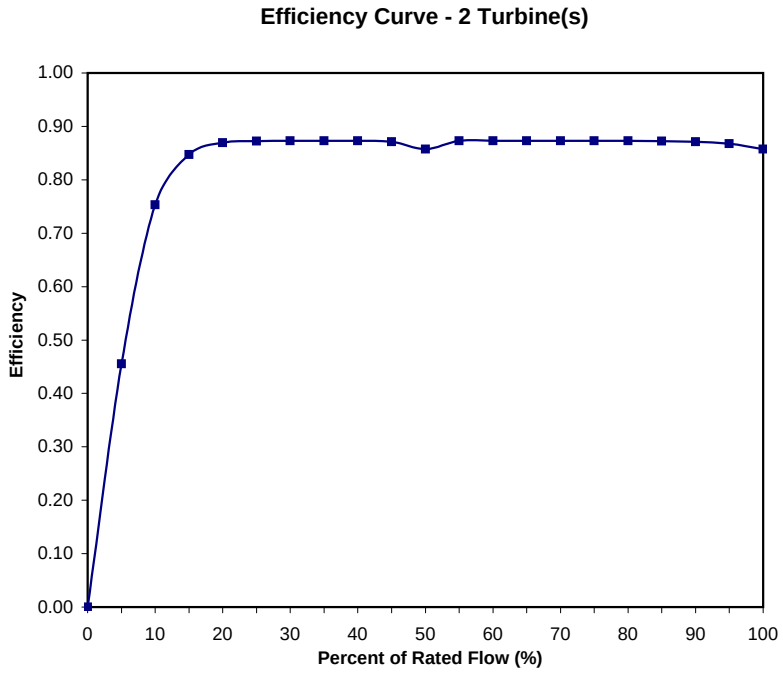
Return to Energy Model sheet

RETScreen® Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	588.00	
Design flow	m³/s	2.000	
Turbine type	-	Pelton	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of jets for impulse turbine	jet	2	1 to 6
Number of turbines	turbine	2	
Small hydro turbine manufacturer		Voith Siemens	
Small hydro turbine model		6 MW	
Turbine manufacture/design coefficient	-	4.5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	0%	-5% to 5%
Turbine peak efficiency	%	87.3%	
Flow at peak efficiency	m³/s	1.3	
Turbine efficiency at design flow	%	85.8%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.00	0	0.00
5%	0.15	1	0.46
10%	0.46	1	0.75
15%	0.64	1	0.85
20%	0.75	1	0.87
25%	0.82	1	0.87
30%	0.85	1	0.87
35%	0.86	1	0.87
40%	0.87	1	0.87
45%	0.87	1	0.87
50%	0.87	1	0.86
55%	0.87	2	0.87
60%	0.87	2	0.87
65%	0.87	2	0.87
70%	0.87	2	0.87
75%	0.87	2	0.87
80%	0.87	2	0.87
85%	0.87	2	0.87
90%	0.87	2	0.87
95%	0.87	2	0.87
100%	0.86	2	0.86



Return to Energy Model sheet

RETScreen® Cost Analysis - Small Hydro Project

Search Marketplace

Costing method: Formula | Currency: User-defined / US$ | Cost references: None

Formula Costing Method			Notes/Range
Input Parameters			
Project country		Guatemala	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	1.00	
Local vs. Canadian labour costs ratio	-	0.70	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	US$/CAD	0.63	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	1.0	
Approx. turbine runner diameter (per unit)	m	0.5	
Project classification:			
Suggested classification	-	Mini	
Selected classification	-	Small	
Existing dam?	yes/no	No	
New dam crest length	m	70.0	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	3%	
Intake and miscellaneous losses	%	0%	1% to 5%
Access road required?	yes/no	Yes	
Length	km	2.5	
Tote road only?	yes/no	No	
Difficulty of terrain	-	1.0	1.0 to 6.0
Tunnel required?	yes/no	Yes	
Length	m	1,700	
Allowable tunnel headloss factor	%	1.0%	4.0% to 7.0%
Percent length of tunnel that is lined	%	10%	15% to 100%
Tunnel excavation method	-	Hand-built	
Tunnel diameter	m	1.8	
Canal required?	yes/no	Yes	
Length in rock	m	2,430	
Terrain side slope in rock (average)	º	30	Max. 45º
Length in impervious soil	m	0	
Terrain side slope in soil (average)	º	0	Max. 15º
Total canal headloss	m	2.43	
Penstock required?	yes/no	Yes	
Length	m	2,200.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	2.0%	1.0% to 4.0%
Pipe diameter	m	1.00	
Average pipe wall thickness	mm	14.9	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	4.4	
Difficulty of terrain	-	1.0	1.0 to 2.0
Voltage	kV	69.0	
Interest rate	%	9.0%	

Initial Costs (Formula Method)	Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study	US$ 401,310	1.00	**US$ 401,310**	3.0%
Development	US$ 426,510	1.00	US$ 426,510	3.2%
Land rights			US$ 300,000	2.3%
Development Sub-total:			**US$ 726,510**	5.5%
Engineering	US$ 303,030	1.00	**US$ 303,030**	2.3%
Energy Equipment	US$ 2,622,060	1.00	**US$ 2,622,060**	19.8%
Balance of Plant				
Access road	US$ 30,870	1.00	US$ 30,870	0.2%
Transmission line	US$ 188,370	1.00	US$ 188,370	1.4%
Substation and transformer	US$ 192,780	1.00	US$ 192,780	1.5%
Penstock	US$ 2,062,620	1.00	US$ 2,062,620	15.6%
Canal	US$ 1,363,950	1.00	US$ 1,363,950	10.3%
Tunnel	US$ 519,120	1.00	US$ 519,120	3.9%
Civil works (other)	US$ 3,381,210	1.00	US$ 3,381,210	25.5%
Balance of Plant Sub-total:	US$ 7,738,920		**US$ 7,738,920**	58.4%
Miscellaneous	US$ 1,459,080	1.00	US$ 1,459,080	11.0%
	US$ -		US$ -	0.0%
	US$ -		US$ -	0.0%
Miscellaneous Sub-total:			**US$ 1,459,080**	11.0%
Initial Costs - Total (Formula Method)	US$ 12,950,910		**US$ 13,250,910**	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	US$ -	US$ -		-	-
Property taxes	%	0.0%	US$ 13,250,910	US$ -		-	-
Water rental	kW	9,011	US$ -	US$ -		-	-
Insurance premium	%	0.50%	US$ 13,250,910	US$ 66,255		-	-
Transmission line maintenance	%	5.0%	US$ 381,150	US$ 19,058		-	-
Spare parts	%	0.50%	US$ 13,250,910	US$ 66,255		-	-
O&M labour	p-yr	1.00	US$ 70,000	US$ 70,000		-	-
GHG monitoring and verification	project		US$ -	US$ -		-	-
Travel and accommodation	p-trip		US$ -	US$ -		-	-
General and administrative	%	10%	US$ 221,567	US$ 22,157		-	-
			US$ -	US$ -		-	-
Contingencies	%	10%	US$ 243,723	US$ 24,372		-	-
Annual Costs - Total				**US$ 268,096**	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Major Maintenance	Cost	10 yr	US$ 1,000,000	**US$ 1,000,000**	-	-
			US$ -	**US$ -**	-	-
			US$ -	**US$ -**	-	-
End of project life		-	US$ -	**US$ -**		

Go to GHG Analysis sheet

RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Small Hydro Project

Use GHG analysis sheet?	Yes	Type of analysis:	Standard
Potential CDM project?	No		

Background Information

Project Information

Project name	High-Head	Project capacity	1.96 MW	**Global Warming Potential of GHG**		
Project location	Zacapa, Guatemala	Grid type	Central-grid	21	tonnes CO_2 = 1 tonne CH_4	(IPCC 1996)
				310	tonnes CO_2 = 1 tonne N_2O	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
#6 oil	100.0%	77.4	0.0030	0.0020	30.0%	8.0%	1.018
Electricity mix	100%	280.4	0.0109	0.0072		8.0%	1.018

Does baseline change during project life? No

Proposed Case Electricity System (Small Hydro Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Electricity system							
Small hydro	100.0%	0.0	0.0000	0.0000	100.0%	8.0%	0.000

GHG Emission Reduction Summary

	Base case GHG emission factor (tCO2/MWh)	Proposed case GHG emission factor (tCO2/MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (t_{CO2})	GHG credits transaction fee (%)	Net annual GHG emission reduction (t_{CO2})
Electricity system	1.018	0.000	52,354	53,321	0.0%	**53,321**

Complete Financial Summary sheet

RETScreen® Financial Summary - Small Hydro Project

Annual Energy Balance

Project name		High-Head			
Project location		Zacapa, Guatemala			
Renewable energy delivered	MWh	56,906	Net GHG reduction	t_{CO2}/yr	53,321
Excess RE available	MWh	-			
Firm RE capacity	kW	1,957			
Grid type		Central-grid	Net GHG emission reduction - 15 yrs	t_{CO2}	799,810

Financial Parameters

Avoided cost of energy	US$/kWh	0.0550	Debt ratio	%	80.0%
RE production credit	US$/kWh	-	Debt interest rate	%	9.0%
			Debt term	yr	10
GHG emission reduction credit	US$/$t_{CO2}$	-	Income tax analysis?	yes/no	No
Avoided cost of capacity	US$/kW-yr	-			
Energy cost escalation rate	%	2.5%			
Inflation	%	2.5%			
Discount rate	%	15.0%			
Project life	yr	15			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	3.0%	US$	401,310	O&M	US$	268,096
Development	5.5%	US$	726,510			
Engineering	2.3%	US$	303,030	Debt payments - 10 yrs	US$	1,651,806
Energy equipment	19.8%	US$	2,622,060	**Annual Costs and Debt - Total**	**US$**	**1,919,902**
Balance of plant	58.4%	US$	7,738,920			
Miscellaneous	11.0%	US$	1,459,080	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**US$**	**13,250,910**	Energy savings/income	US$	3,129,830
				Capacity savings/income	US$	-
Incentives/Grants		US$	-			
				Annual Savings - Total	**US$**	**3,129,830**
Periodic Costs (Credits)						
Major Maintenance		US$	1,000,000	Schedule yr # 10		
		US$	-			
		US$	-			
End of project life -		US$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	54.0%			
After-tax IRR and ROI	%	54.0%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	4.6			
Year-to-positive cash flow	yr	2.0	Project equity	US$	2,650,182
Net Present Value - NPV	US$	8,032,888	Project debt	US$	10,600,728
Annual Life Cycle Savings	US$	1,373,761	Debt payments	US$/yr	1,651,806
Benefit-Cost (B-C) ratio	-	4.03	Debt service coverage	-	1.78

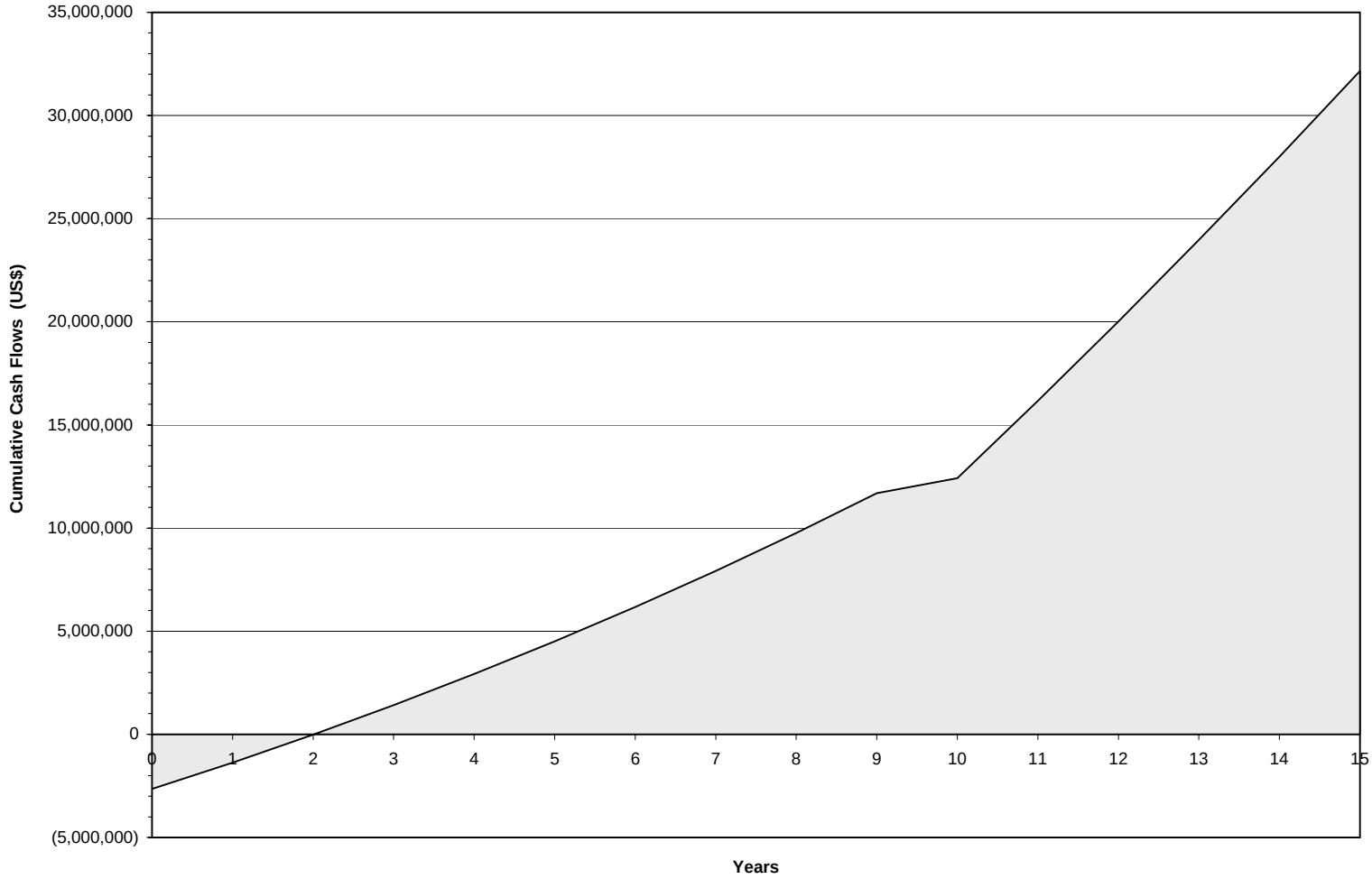
Yearly Cash Flows

Year #	Pre-tax US$	After-tax US$	Cumulative US$
0	(2,650,182)	(2,650,182)	(2,650,182)
1	1,281,472	1,281,472	(1,368,710)
2	1,354,804	1,354,804	(13,907)
3	1,429,969	1,429,969	1,416,062
4	1,507,013	1,507,013	2,923,076
5	1,585,984	1,585,984	4,509,059
6	1,666,929	1,666,929	6,175,988
7	1,749,897	1,749,897	7,925,885
8	1,834,939	1,834,939	9,760,824
9	1,922,108	1,922,108	11,682,932
10	731,371	731,371	12,414,304
11	3,754,844	3,754,844	16,169,148
12	3,848,715	3,848,715	20,017,863
13	3,944,933	3,944,933	23,962,796
14	4,043,556	4,043,556	28,006,352
15	4,144,645	4,144,645	32,150,997

Cumulative Cash Flows Graph

Small Hydro Project Cumulative Cash Flows
High-Head, Zacapa, Guatemala

Renewable energy delivered (MWh/yr): 56,906 **Total Initial Costs: US$ 13,250,910** **Net average GHG reduction (t_{CO2}/yr): 53,321**



IRR and ROI: 54% **Year-to-positive cash flow: 2 yr** **Net Present Value: US$ 8,032,888**

RETScreen® Sensitivity and Risk Analysis - Small Hydro Project

Use sensitivity analysis sheet?	Yes	Perform analysis on	After-tax IRR and ROI	
Perform risk analysis too?	Yes	Sensitivity range	20%	
Project name	High-Head	Threshold	15.0	%
Project location	Zacapa, Guatemala			

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of energy (US$/kWh) 0.0440 -20%	0.0495 -10%	**0.0550 0%**	0.0605 10%	0.0660 20%
45,525	-20%	16.8%	24.3%	32.2%	40.6%	49.4%
51,215	-10%	24.3%	33.3%	42.8%	52.8%	63.1%
56,906	0%	32.2%	42.8%	**54.0%**	65.4%	77.1%
62,597	10%	40.6%	52.8%	65.4%	78.3%	91.3%
68,287	20%	49.4%	63.1%	77.1%	91.3%	105.6%

Initial costs (US$)		Avoided cost of energy (US$/kWh) 0.0440 -20%	0.0495 -10%	**0.0550 0%**	0.0605 10%	0.0660 20%
10,600,728	-20%	51.4%	65.8%	80.5%	95.3%	110.2%
11,925,819	-10%	40.5%	52.8%	65.6%	78.6%	91.8%
13,250,910	0%	32.2%	42.8%	**54.0%**	65.4%	77.1%
14,576,001	10%	25.8%	35.0%	44.7%	54.9%	65.3%
15,901,092	20%	20.8%	28.8%	37.3%	46.3%	55.6%

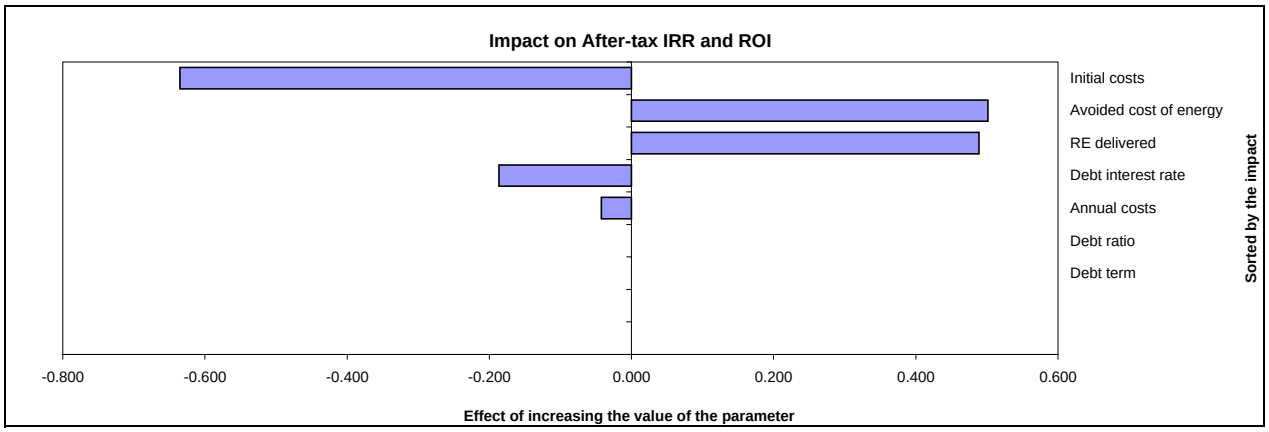
Annual costs (US$)		Avoided cost of energy (US$/kWh) 0.0440 -20%	0.0495 -10%	**0.0550 0%**	0.0605 10%	0.0660 20%
214,476	-20%	34.0%	44.7%	55.9%	67.4%	79.1%
241,286	-10%	33.1%	43.8%	54.9%	66.4%	78.1%
268,096	0%	32.2%	42.8%	**54.0%**	65.4%	77.1%
294,905	10%	31.3%	41.9%	53.0%	64.4%	76.1%
321,715	20%	30.5%	41.0%	52.0%	63.5%	75.1%

Debt interest rate (%)		Debt ratio (%) 64.0% -20%	72.0% -10%	**80.0% 0%**	88.0% 10%	96.0% 20%
7.2%	-20%	39.9%	46.7%	58.3%	84.8%	215.0%
8.1%	-10%	39.0%	45.3%	56.1%	80.7%	201.1%
9.0%	0%	38.1%	43.9%	**54.0%**	76.6%	186.9%
9.9%	10%	37.1%	42.5%	51.8%	72.4%	172.6%
10.8%	20%	36.1%	41.1%	49.6%	68.3%	158.2%

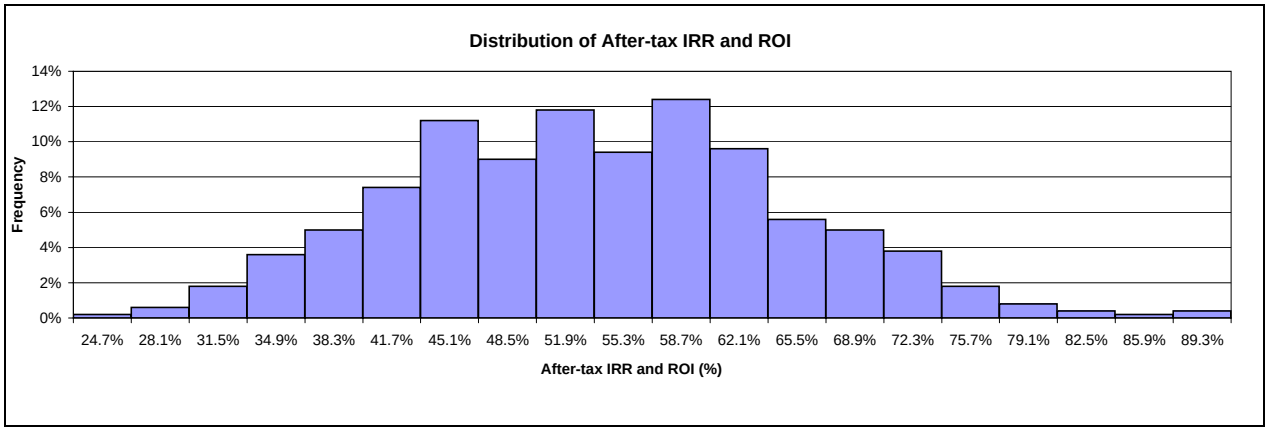
Debt interest rate (%)		Debt term (yr) 8.0 -20%	9.0 -10%	**10.0 0%**	11.0 10%	12.0 20%
7.2%	-20%	50.7%	54.7%	58.3%	61.4%	64.1%
8.1%	-10%	48.8%	52.7%	56.1%	59.2%	61.8%
9.0%	0%	47.0%	50.6%	**54.0%**	56.9%	59.5%
9.9%	10%	45.1%	48.6%	51.8%	54.6%	57.1%
10.8%	20%	43.3%	46.5%	49.6%	52.3%	54.7%

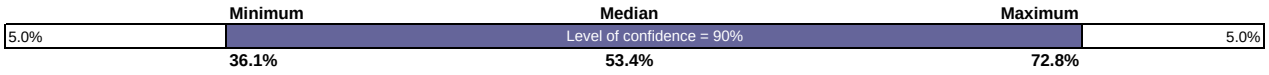
Risk Analysis for After-tax IRR and ROI

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	US$/kWh	0.0550	15%	0.0468	0.0633
RE delivered	MWh	56,906	15%	48,370	65,442
Initial costs	US$	13,250,910	20%	10,600,728	15,901,092
Annual costs	US$	268,096	15%	227,881	308,310
Debt ratio	%	80.0%	0%	80.0%	80.0%
Debt interest rate	%	9.0%	30%	6.3%	11.7%
Debt term	yr	10	0%	10	10



Median	%	53.4%
Level of risk	%	10%
Minimum within level of confidence	%	36.1%
Maximum within level of confidence	%	72.8%





User-Defined Sheet - Small Hydro Project

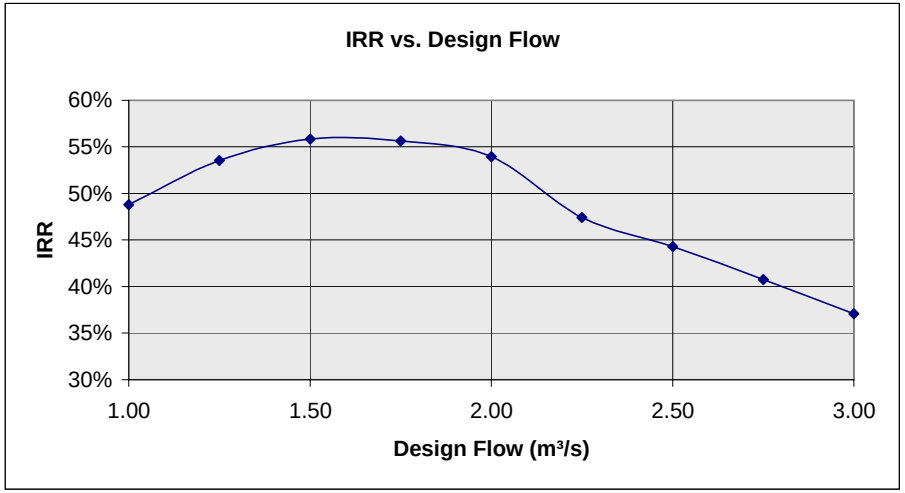
Optimum Design Flow Calculation

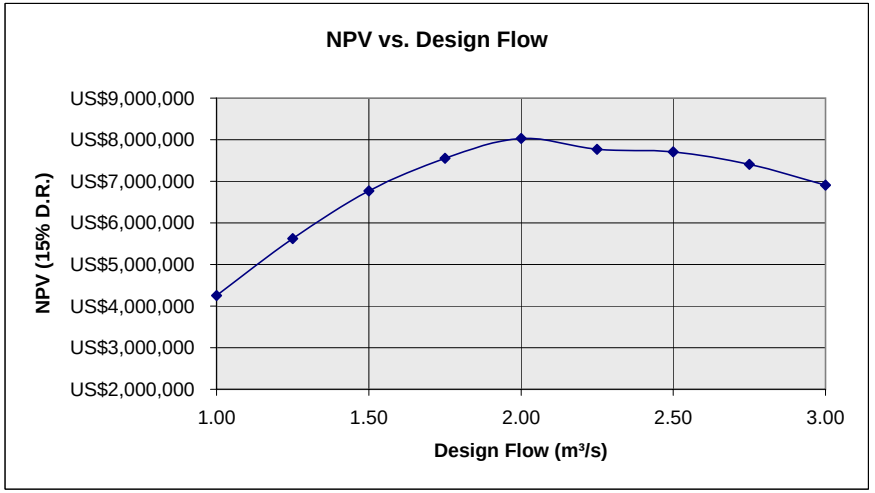
Sensitivity Analysis

Flow (m^3/s)	Capacity (kW)	Cost (US$)	G. Revenue (US$)	O&M (US$)	IRR (%)	NPV (D.R = 15%)
1.00	4,443	US$ 8,160,510	US$ 1,879,105	US$ 201,089	49%	US$ 4,256,765
1.25	5,579	US$ 9,490,440	US$ 2,262,158	US$ 218,554	54%	US$ 5,623,000
1.50	6,719	US$10,777,530	US$ 2,607,090	US$ 235,500	56%	US$ 6,771,142
1.75	7,863	US$12,028,080	US$ 2,892,446	US$ 251,965	56%	US$ 7,551,120
2.00	9,011	US$13,250,910	US$ 3,129,830	US$ 268,096	54%	US$ 8,032,888
2.25	10,161	US$15,062,160	US$ 3,335,868	US$ 291,308	47%	US$ 7,769,817
2.50	11,314	US$16,343,580	US$ 3,500,098	US$ 308,071	44%	US$ 7,705,857
2.75	12,470	US$17,604,840	US$ 3,626,387	US$ 324,628	41%	US$ 7,404,180
3.00	13,627	US$18,848,460	US$ 3,720,867	US$ 340,933	37%	US$ 6,904,361

Optimum Design Flow Selected

2.00	9,011	US$13,250,910	US$ 3,129,830	US$ 268,096	54%	US$ 8,032,888





- The head losses in the canals and tunnels (if operated as free flowing canals) must be deducted from the gross head value entered in the Energy Model worksheet. In this case, a total of about 4 m must be deducted from the total available gross head of 592 m, which is calculated as the difference between the daily reservoir full supply level of 880 m and the centre line of the pelton turbines at 288 m (280 m plus 8 m to allow for extreme flood levels and a margin of safety). Gross head for the purposes of the RETScreen analysis can, therefore, be estimated to be 588 m.
- The RETScreen analysis suggests the maximum plant output will be 11.2 MW at the point of interconnection (before parasitic energy losses and transformer losses). Approximately 7% less than the 12 MW, which were installed.
- The volume of storage in the storage reservoir equates to approximately 14 hours of plant operation at full output, which would produce, on an annual basis, an increase of about 156 MWh or just 0.2% of the estimated energy production. The storage can, however, be used to increase plant efficiency during periods of low flow by allowing the turbines to run for shorter times at higher flows. This effect could be approximated by adjusting the turbine efficiency curve in the low-flow range. In this case, however, the minimum flow is about 33% of the design flow of one turbine and efficiency cannot be improved. The effect of the available storage will be negligible and, therefore, the operation can be classified as "run-of-river."
- Sheet 1 (blank worksheet provided to allow the user to prepare a customized RETScreen project analysis) provides an example of the project pre-tax IRR vs. Design Flow. Using NPV as the measure for evaluating the optimum design flow (and thus optimum installed turbine capacity), a number of RETScreen iterations were performed to determine that a design flow of approximately 2.0 m^3/s yields the highest NPV. Choosing other financial parameters (e.g. IRR) as indicators of optimal financial performance may yield somewhat different design flow rates. As built, the final project used a design flow rate of 2.5 m^3/s. One benefit of the higher turbine capacity is that it gives the developer the possibility to take advantage of the value of peak power, which has not been included in this analysis.
- For this project, the discount rate is interpreted as being equal to the "required rate of return" (see Online User Manual definition for discount rate), which is 15%. This means that as long as the project's NPV is above zero, the desired rate of return has been achieved and the project is considered to be financially feasible according to the developer's criteria.
- In the "formula" costing method, RETScreen suggests that this project should be classified as a "mini" project but "small" has been used instead, as it was determined that the "small" classification was more appropriate.
- The costs and benefits of using a penstock with a varying diameter cannot be assessed using the RETScreen "formula" costing method. The formula method does, however, account for the increased wall thickness that is required as the pressure increases over the length of the penstock.